

there was a definite arousal of visual sensation by the alternating field; the effect appeared more like an alternate intensification and inhibition of whatever sensory process was already in progress. That is to say, the idio-retinal light which is present before the current is turned on is increased and decreased alternately.

A KINETIC THEORY OF GRAVITATION.¹

EVER since Sir Isaac Newton enunciated the law of universal gravitation, more than two hundred years ago, philosophers have speculated on the nature of that mysterious agency which links every atom of matter in the universe with every other atom. Newton found himself unable to offer any adequate explanation.

Since Newton's time several theories of gravitation have been proposed; but all, of which I am aware, are open to strong objections, and are not considered even promising by physicists.

Study of the nature of gravitation is beset with unusual difficulties, because gravitation is ever with us and about us; it is the one universal phenomenon, and we cannot escape from its influence—cannot obtain any outside point of view.

Gravitation is often described as a feeble force; and so it is, from one point of view. It is difficult to measure, or even to detect, attraction between two small bodies. But when the bodies are of planetary size the aggregate attraction of their molecules is enormous. It is easy to calculate that the attraction between the earth and the moon, which is just sufficient to retain the latter in its orbit, would, if replaced by a steel cable, require that the cable be about five hundred miles in diameter in order to withstand the strain. Between the earth and sun, the cable would have to be nearly as large in diameter as the earth; and attraction between the components of some double stars is millions of times greater than between the earth and sun (Lodge). So tremendous a phenomenon as gravitation, a phenomenon compared with which all others seem trivial, must have a mighty origin.

That gravitation is a phenomenon of the all-pervading æther is beyond reasonable doubt. This is so generally conceded that it need not be argued. But how does the gravitative influence originate? How is it transmitted and maintained? What is the *mechanism* of gravitation? It is the purpose of this paper to attempt an answer to these questions.

Let us consider what happens to a falling body. We know that it gathers kinetic energy from some source, as evidenced by its acceleration; that this energy may do external work or develop heat; that the amount of energy gathered is measured directly by the distance fallen through (within the limits of uniform gravitation), irrespective of the time or rate of falling. When the distance fallen through is of inter-planetary magnitude, and the attracting body large, the gathered energy is enormous, sufficient, if converted into heat, to vapourise the most refractory falling body.

We are here confronted with the question, Whence comes the energy acquired by a falling body? Certainly it was not inherent in the body before the fall, as evidenced by the fact that during unimpeded fall none of the physical or chemical attributes of the body, aside from the acquired motion, changes in the slightest degree.

We have been taught that before the fall the body was endowed with "potential energy of position," which is converted into kinetic energy during the fall. I think "energy of position" is an unfortunate term, because it is so very inadequate. To me it explains nothing. The case is not like that of a flexed spring, where there is internal molecular strain or displacement.

Let us imagine a pound-weight of iron, for instance, raised from the surface of the earth to a point near the moon in a line joining the centres of the two bodies, the point so chosen that the opposing attraction of the earth and the moon shall exactly balance each other, leaving orbital motion out of consideration.

On the surface of the earth the pound-weight had some so-called "potential energy of position," because it was capable of falling into a pit; but in its new position near

the moon, this potential energy not only has not been augmented, but has disappeared entirely; the pound-weight, left free to move, remains stationary; and yet we must have expended more than twenty million foot-pounds of energy in overcoming the attraction of the earth and lifting the weight to its new position. This amount of energy would be sufficient to impart to the weight a velocity more than ten times greater than that of the swiftest cannon-ball, or, if converted into heat, would be many times more than sufficient to raise the iron weight to dazzling incandescence and then vapourise it. Now, in lifting the weight, this large amount of energy has disappeared utterly. We cannot believe that the whole or any part of it has been annihilated; it must, in some form, be resident somewhere. I think no one will contend that this energy is resident, in any form, in the cold, motionless pound-weight. I believe it was absorbed by, and is now resident in, the æther through which the weight was raised. Conversely, if this be true, a falling body must acquire its energy from the æther through which it falls. This is a fundamental idea to which I invite attention. Faraday glimpsed it long ago, and others have appreciated it more clearly since his time. But, so far as I am aware, no one has realised its significance.

This view of gravitation implies that the æther is endowed with very great intrinsic energy in some form. Many men of science now hold that the æther is so endowed, and that the amount of this intrinsic energy is enormous. Sir Oliver Lodge ("The Ether of Space") appears to regard this energy as potential in form, and estimates the intrinsic energy of a single cubic millimetre of the æther to be almost inconceivably vast. He says, "All potential energy exists in the ether." Sir J. J. Thomson says, "All kinetic energy is kinetic energy of the ether."

I conceive the æthereal energy involved in gravitation to be kinetic rather than potential, the latter involving strain or stress. Newton, and later Maxwell, assumed that bodies produce a stress in the æther about them of such nature as to account for gravitation, but they were unable to imagine any physical cause for the stress.

All the past theories of gravitation of which I am aware, except the corpuscular theory of La Sage, appear to regard gravitating matter as the seat of the gravitative influence, the surrounding æther, by induced stress or otherwise, acting simply as the medium of transmission. I cannot see that any of these theories accounts for the energy acquired by a falling body.

My own view of gravitation differs from these radically. I believe that kinetic energy of the æther is the fundamental cause of gravitation, and that a gravitating body plays a secondary rôle only in disturbing the normally uniform distribution of the æther's energy, in a manner I shall endeavour to explain later.

Let us assume, then, that the æther is endowed with very great kinetic energy normally uniform in distribution.

Kinetic energy implies motion of something possessed of inertia. Now, inertia is a fundamental attribute of the æther. Sir J. J. Thomson holds that all inertia is inertia of the æther. The æther is highly elastic also, which, with its inertia, enables it to possess kinetic energy in wave form, as exemplified in radiation. By the term wave, I mean progressive motion locally periodic; doubtless the æther as a whole is stationary. Hence we may consider the kinetic energy of the æther as consisting in æther waves of some kind.

These waves, vast in aggregate energy, eternal in persistence, without finite source or destination, are imagined as being propagated in straight lines in every conceivable direction. This isotropic distribution of kinetic energy, essential to my theory of gravitation, was, for me, a difficult conception until I reflected that isotropic radiant energy is approximately realised in the interior of any furnace with uniformly heated walls.

Any kind of waves capable of exerting motive action on the atoms or molecules of matter will fulfil the requirements; but I shall first consider the transverse, electromagnetic waves of radiation, because these are the kind of æther waves we are familiar with.

Of course, intrinsic æther waves, if of the radiation kind, cannot be of any frequency at present known to us as radiation, because then all bodies would become heated.

¹ Paper read before the American Association for the Advancement of Science, December, 1910, by Mr. Charles F. Brush.

But we can easily imagine them of such extremely low frequency that the molecules or atoms of matter cannot respond to them—cannot vibrate in unison with them—molecular resonance cannot be established; hence no conversion of the æther's energy *directly* into heat in the ordinary way can take place.

We are familiar with the dissipation or degeneration of the higher forms of energy into heat, and the continual degradation of heat to lower degree; that is to say, less violent molecular vibration and more general distribution. As is well known, it is only through this degradation or running down of natural energy that we are enabled to utilise some of it. Lord Kelvin called this function of energy "motivity" (we now call it entropy), and said the motivity of the universe tends to zero.

We know that ordinary radiation waves in the æther persist indefinitely and without change of frequency or direction until they encounter matter, when they are absorbed and converted into heat, only to be radiated again, usually in longer waves, to some colder body. This degradation of wave frequency continues until we can no longer follow it. I beg to suggest that the ultimate destination of this wave energy is that vast reservoir of kinetic energy intrinsic to the æther. We may liken the waves of radiant energy, which we apprehend as light and heat, to wind ripples on the surface of water, which continually degenerate in wave frequency until they are absorbed into and become a part of the mighty swell of the ocean.

Thus we may, perhaps, regard the æther's intrinsic energy as energy in its lowest form—Kelvin's zero of "motivity." But fortunately we may, and do, get some of this energy back in available form in several ways, as, for instance, when a falling body is arrested and develops heat; some of our wind ripples are then returned to us.

When two gigantic astronomical bodies collide under the influence of gravitation, as sometimes happens, we witness in far distant space the birth of a nebula. The inconceivably vast amount of heat developed by the collision converts both bodies into luminous vapour, which expands with incredible rapidity into the nebulous cloud. This heat energy must in course of time degenerate back into the æther whence it came, though billions of years may be required; and during all this time the energy has "motivity." We may picture the stupendous result of the collision as only a local splash in the æther's mighty ocean of energy.

Having postulated that the æther is endowed with very great intrinsic kinetic energy in wave form of some kind, that the waves are propagated in straight lines in every conceivable direction, *i.e.* the wave energy is isotropic, and that this energy is distributed uniformly throughout the universe except in so far as the distribution is disturbed by the presence of matter, I shall endeavour to explain my conception of the mechanism of gravitation.

For illustration in terms of the known, let us imagine a closed space having uniformly luminous walls of such character that every point on their surface radiates light in all internal directions. The enclosed space may be of any shape, but for the sake of simplicity let it be spherical or cubical, and large, say as large as a lecture-room. The space will be filled with isotropic radiant energy uniformly distributed—any cubic centimetre of space containing as much energy as any other.

Next let us picture a small opaque body suspended anywhere in our luminous space. The body may be of any shape we may imagine an atom or molecule to have; but, again for simplicity, let it be spherical—say a small grain of shot, and let it be located near the centre of the space.

The small body will absorb the light which falls upon it, and will cast a spherical shadow, the depth or intensity of which will vary inversely with the square of the distance from the centre of the body; and the shadow will extend to the confines of the enclosure, however large the latter may be. We cannot perceive the shadow, but we know it is there. It is true that the body will soon acquire the temperature of its surroundings, and radiate as much energy as it receives; but for the purpose of this illustration let us consider only the high-frequency light energy.

As is well known, the æther waves of light will exert a slight pressure on the body. But in the case supposed

the pressure will be equal on all sides, and no effort toward translation can result.

Now let us introduce a second small body, similar to the first, and some distance from it. This also will cast a spherical shadow like the first. The two shadows will intersect, and each body will lie within the shadow of the other. In other words, each body will be partially shielded by the other from the æther waves coming from that direction. Hence the light pressure will be less on that side of each body which faces toward the other than on the side which is turned away, and the bodies will be urged toward each other by the excess of light pressure on the side turned away. This excess of pressure will vary with the inverse square of the distance between the centres of the bodies so long as the ratio of distance to diameters remains large.

The æther waves concerned in gravitation cannot, however, be like the light waves I have just used for illustration, because light waves heat bodies on which they fall; and their pressure is almost wholly superficial, it does not reach molecules much below the surface, and hence bears little relation to mass.

But let us substitute for the short and feeble waves of light powerful waves, still of the radiant kind, but of such great length and slow frequency that, as before explained, they do not excite the molecular vibrations which we appreciate as heat, and hence are not absorbed by matter; they pass freely through all bodies, bathing the interior molecules as effectually as those on the surface.

Under these conditions each molecule or atom or unit of a gravitating body will have its own spherical shadow or field of influence, and the gravitative force acting on the body will vary directly with the sum of its units, *i.e.* with its mass.

The spherical shadow which I have pictured as the field of influence of each atom or material unit implies that the atom has caused, principally in its immediate neighbourhood, a diminution of the æther's energy. Let us further imagine this subtracted energy resident in the atom as kinetic energy of translation in many paths, almost infinitesimally short and in every direction, but without collisions, because neighbouring atoms follow very nearly parallel paths. We may then picture the collective atoms or molecules of matter buffeted about in every direction by the æther waves in which they are entangled, like a suspended precipitate in turbulent water.

Each atom or molecule may be regarded as a centre of activity due to its kinetic energy of translation, with continual absorption and restitution of the æther's energy, normally equal in amount. The manner in which this molecular activity maintains, in effect, the supposed spherical shadow, requires explanation, which I shall attempt in a future paper.

Of the several components into which the composite motion of each atom can be resolved, that one lying in the direction of an attracting body will be the greatest, because the waves from that direction, being partially intercepted by the attracting body, are weakest, and the atom will be *pushed* in that direction by the superior waves behind it. If free to fall, the atom will continually absorb more energy from the stronger waves behind it than it restores to the weaker waves in front, and will thus acquire additional kinetic energy of translation in the line of fall, measured directly by the number of waves involved, *i.e.* by the distance moved. Conversely, if the atom be forced away from the attracting body, restitution of energy will exceed absorption, and the energy expended in moving the atom against attraction will be transferred to the æther.

It will be seen that gravitation is a *push* toward the attracting body, and not a pull. It is clear, also, that the velocity which a falling body can acquire tends asymptotically to a limit, which is the velocity of the æther waves which push it—the velocity of light, if transverse waves are involved.

I have already intimated that any kind of æther waves capable of imparting motion (not internal vibration) to the atoms of matter will fulfil the requirements of my theory, but have thus far discussed only transverse waves.

Let us now consider longitudinal waves—waves of compression and rarefaction, like sound waves in air and in

elastic liquids and solids. The "spherical shadow" conception which I have employed in connection with transverse waves applies equally well here.

So far as I am aware, longitudinal waves in the æther are unknown, but that such waves have not been observed is not convincing argument that they do not exist.

Assuming, then, that some, or perhaps much, of the intrinsic energy of the æther is embodied in longitudinal waves, we have only to find some motive action of such waves on atoms of matter to account for gravitation. Adequate motive connection may perhaps be effected by the locally alternating flow and ebb—acceleration and retardation of the æther in which the atoms are enmeshed, incident to its wave motion. We have ample reason for believing that the æther does obtain a grip of some sort on the atoms of an accelerating (falling) body and a retarding (rising) body, from which it follows that accelerating and retarding æther, as in a wave of compression, must grip a comparatively stationary atom.

Certain facts of astronomy apparently require that gravitational attraction between bodies, however distant from each other, must, in effect, be instantaneous; that is to say, the line of apparent attraction between them is a straight line joining their centres. I believe my theory meets this condition, but shall reserve discussion of the point for a future paper.

I feel much diffidence in presenting the foregoing rough draft of a theory of gravitation, but I cannot avoid the belief that it contains some germs of truth, perhaps the real key to the great mystery, though, if this be true, I have no doubt used the key clumsily and imperfectly.

If the æther-wave theory of gravitation is, in the main, the true one, it offers some hope of experimental verification. Provided the waves are of one principal frequency, or even of several, we may find something, doubtless of molecular magnitude only, which will oscillate in unison with them so that resonance can occasionally be established and a cumulative effect be obtained sufficient to manifest itself as heat.

In searching for some natural phenomenon of this nature, I thought of the thermal condition of the upper atmosphere as a possible case. The mean molecular velocity of a gas at some temperature, in connection with the mean free path of its molecules at some particular pressure or pressures, may possibly afford the necessary conditions for fortuitous resonance, with development of some slight amount of heat by the increased violence of inter-molecular collisions. I have done much experimental work on these lines during the past year, but, notwithstanding refinement of method and manipulation, the results have thus far been unsatisfactory. The work is still in progress, however, and investigation of other phenomena is contemplated.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Mr. R. C. B. Gardner has been appointed assistant to the superintendent of the Museum of Zoology, and the appointment has received the consent of the Vice-Chancellor.

The special board for biology and geology has nominated Mr. J. F. Gaskell to use the University table at Naples for three months, and Mr. W. O. R. King to occupy the University table at the laboratory of the Marine Biological Association at Plymouth.

On Thursday, April 27, a Grace will be brought before the Senate suggesting that the laboratory of experimental psychology syndicate be authorised to obtain tenders for the erection of a building for the psychological laboratory in accordance with Mr. Jackson's plans, and that the Vice-Chancellor be authorised to sign the contract for the work provided that the total cost does not exceed 4250*l*.

It is announced in the *Revue scientifique* that Mr. Arthur Krupp has given 50,000 crowns to the Vienna School of Arts and Crafts towards the establishment of an aviation laboratory.

In connection with the celebration of the centenary of the University of Breslau, Dr. P. Schottlaender has given

the University 250,000 marks, the interest of which, says the *Revue scientifique*, is to be devoted to the provision of travelling exhibitions or to the purposes of research.

At a meeting of the London branch of the Association of Teachers in Technical Institutions, to be held on Saturday, March 25, at the South-Western Polytechnic, Chelsea, S.W., a conference on the organisation of technical instruction, especially in connection with the higher branches, will be opened by Dr. R. T. Glazebrook, F.R.S., director of the National Physical Laboratory.

THE London Inter-collegiate Scholarships Board announces that an examination will be held on May 9 for eighteen entrance scholarships and exhibitions, of an aggregate total value of about 1500*l*., open to men and women, and tenable in the faculties of arts, science, and engineering of University College, King's College, and the East London College. Particulars and entry forms may be obtained from the secretary of the Board, Mr. A. E. G. Attoe, University College, Gower Street, W.C.

MR. ALEXANDER SIEMENS, president of the Institution of Civil Engineers, speaking at the annual dinner of the institution on March 17, said that the institution proposes to inaugurate a conference on engineering education during the summer with the object of making clear the proper way of preparing young men for the profession of engineering. The passing of examinations is part of what is needed, he pointed out, but not all. The great thing is practical training, so that young men may know how to employ their theoretical knowledge and be prepared to take up any branch of engineering which fate may drive them to. Mr. Siemens hopes that the institution will have an opportunity at the forthcoming Imperial Conference to represent to the Colonies the desirability of recognising the qualifications of its members and of according them uniform treatment throughout the Empire.

THE Home Secretary has appointed a committee to inquire into the constitution, management, discipline, and education of reformatory and industrial schools in England and Wales. The inquiry will include a consideration of the relation of the schools to education committees and other authorities, and the qualifications of superintendents and other officers; variation in the types of schools, and whether further provision is necessary for the proper grading of boys and girls; the suitability of ships for use as schools; the preparation given boys for entry into industrial or other careers, and the training and disposal of girls; the care of boys and girls after leaving the schools and the relation of the schools in this connection to existing institutions for the welfare of young persons. The committee appointed is representative in character, and Mr. C. F. G. Masterman, M.P., is the chairman. Mr. A. Maxwell, of the Home Office, will act as secretary.

THE Board of Education has found it impossible to complete the preparation of the new grant regulations for technical schools, schools of art, and other forms of provision of further education in England and Wales, at as early a date as was suggested in the prefatory memorandum to the regulations issued last August. This being so, the Board feels that to bring new regulations into force by August 1 next would allow insufficient time to education authorities for accommodating their arrangements to the requirements of the new regulations. The grant regulations for 1910 are, therefore, to be continued in force during the educational year 1911-12, and the Board hopes in the course of the coming summer to issue the new regulations, which will not, however, become operative until the educational year 1912-13. The new regulations may thus be in the hands of education authorities a year before they come into force. The Board announces, however, that it will not be necessary similarly to defer the issue or the operation of the new regulations for university institutions. The Board contemplates issuing separate provisions in respect of the educational year 1911-12 for the payment of grant in aid of approved courses provided by university institutions. Any courses so aided will cease to be eligible for recognition under the Board's regulations for technical schools. New regulations for the science and art examinations, the National competition, and the various forms of scholarships and exhibitions given and aided by the Board are under consideration, and it is hoped that